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Preliminary Design Formulas

Calculators! Examples! Conversions!

List of 27 Preliminary Design Formulas

Preliminary Design

1) Crew Weight given Fuel and Empty Weight Fraction

Open Calculator

$$W_c = DTW \cdot (1 - E_f - F_f) - PYL$$

$$12600\text{kg} = 250000\text{kg} \cdot (1 - 0.5 - 0.4) - 12400\text{kg}$$

2) Crew Weight given Takeoff Weight

Open Calculator

$$W_c = DTW - PYL - FW - OEW$$

$$12600\text{kg} = 250000\text{kg} - 12400\text{kg} - 100000\text{kg} - 125000\text{kg}$$

3) Design Range given Range Increment

Open Calculator

$$R_D = R_H - \Delta R$$

$$52\text{km} = 123\text{km} - 71\text{km}$$

4) Empty Weight Fraction

Open Calculator

$$E_f = \frac{OEW}{DTW}$$

$$0.5 = \frac{125000\text{kg}}{250000\text{kg}}$$

5) Empty Weight Fraction given Takeoff Weight and Fuel Fraction

Open Calculator

fx $$E_f = 1 - F_f - \frac{PYL + W_c}{DTW}$$

ex $$0.5 = 1 - 0.4 - \frac{12400kg + 12600kg}{250000kg}$$

6) Empty Weight given Empty Weight Fraction

Open Calculator

fx $$OEW = E_f \cdot DTW$$

ex $$125000kg = 0.5 \cdot 250000kg$$

7) Empty Weight given Takeoff Weight

Open Calculator

fx $$OEW = DTW - FW - PYL - W_c$$

ex $$125000kg = 250000kg - 100000kg - 12400kg - 12600kg$$

8) Fuel Fraction

Open Calculator

fx $$F_f = \frac{FW}{DTW}$$

ex $$0.4 = \frac{100000kg}{250000kg}$$

9) Fuel Fraction given Takeoff Weight and Empty Weight Fraction

Open Calculator

fx $$F_f = 1 - E_f - \frac{PYL + W_c}{DTW}$$

ex $$0.4 = 1 - 0.5 - \frac{12400\text{kg} + 12600\text{kg}}{250000\text{kg}}$$

10) Fuel Weight given Fuel Fraction

Open Calculator

fx $$FW = F_f \cdot DTW$$

ex $$100000\text{kg} = 0.4 \cdot 250000\text{kg}$$

11) Fuel Weight given Takeoff Weight

Open Calculator

fx $$FW = DTW - OEW - PYL - W_c$$

ex $$100000\text{kg} = 250000\text{kg} - 125000\text{kg} - 12400\text{kg} - 12600\text{kg}$$

12) Harmonic Range given Range Increment

Open Calculator

fx $$R_H = \Delta R + R_D$$

ex $$123\text{km} = 71\text{km} + 52\text{km}$$

13) Helicopter Flying Range

Open Calculator

fx $$R = 270 \cdot \frac{G_T}{W_a} \cdot \frac{C_L}{C_D} \cdot \eta_r \cdot \frac{\xi}{c}$$

ex $$1002.552\text{km} = 270 \cdot \frac{37.5\text{kg}}{1001\text{N}} \cdot \frac{1.1}{0.51} \cdot 3.33 \cdot \frac{2.3}{0.6\text{kg/h/W}}$$

14) Maximum Lift over Drag

Open Calculator

fx $$LDmax_{ratio} = K_{LD} \cdot \left(\frac{AR}{\frac{S_{wet}}{S}} \right)^{0.5}$$

ex $$19.79899 = 14 \cdot \left(\frac{4}{\frac{10.16m^2}{5.08m^2}} \right)^{0.5}$$

15) Optimum Range for Jet Aircraft in Cruising Phase

Open Calculator

fx $$R = \frac{V_{L/D(max)} \cdot LDmax_{ratio}}{c} \cdot \ln\left(\frac{W_i}{W_f} \right)$$

ex $$1002.472km = \frac{42.9kn \cdot 19.7}{0.6kg/h/W} \cdot \ln\left(\frac{514kg}{350kg} \right)$$

16) Optimum Range for Prop-Driven Aircraft in Cruising Phase

Open Calculator

fx $$R_{opt} = \frac{\eta \cdot LDmax_{ratio}}{c} \cdot \ln\left(\frac{W_i}{W_f} \right)$$

ex $$42.24347km = \frac{0.93 \cdot 19.7}{0.6kg/h/W} \cdot \ln\left(\frac{514kg}{350kg} \right)$$

17) Payload Weight given Fuel and Empty Weight Fractions

Open Calculator

fx $$PYL = DTW \cdot (1 - E_f - F_f) - W_c$$

ex $$12400kg = 250000kg \cdot (1 - 0.5 - 0.4) - 12600kg$$

18) Payload Weight given Takeoff Weight

Open Calculator

fx $$PYL = DTW - OEW - W_c - FW$$

ex $$12400\text{kg} = 250000\text{kg} - 125000\text{kg} - 12600\text{kg} - 100000\text{kg}$$

19) Preliminary Endurance for Jet Aircraft

Open Calculator

fx $$P_E = \frac{LDmax_{ratio} \cdot \ln\left(\frac{W_i}{W_f}\right)}{c}$$

ex $$45423.09\text{s} = \frac{19.7 \cdot \ln\left(\frac{514\text{kg}}{350\text{kg}}\right)}{0.6\text{kg/h/W}}$$

20) Preliminary Endurance for Prop-Driven Aircraft

Open Calculator

fx $$E = \frac{LDEmax_{ratio} \cdot \eta \cdot \ln\left(\frac{W_{L(beg)}}{W_{L,end}}\right)}{c \cdot V_{(Emax)}}$$

ex $$2028.252\text{s} = \frac{26 \cdot 0.93 \cdot \ln\left(\frac{400\text{kg}}{300\text{kg}}\right)}{0.6\text{kg/h/W} \cdot 40\text{kn}}$$

21) Preliminary Take Off Weight Built-up for Manned Aircraft

Open Calculator

fx $$DTW = PYL + OEW + FW + W_c$$

ex $$250000\text{kg} = 12400\text{kg} + 125000\text{kg} + 100000\text{kg} + 12600\text{kg}$$

22) Preliminary Take off Weight Built-Up for Managed Aircraft given Fuel and Empty Weight Fraction

Open Calculator

fx $$\mathrm{DTW} = \frac{\mathrm{PYL} + \mathrm{W_c}}{1 - \mathrm{F_f} - \mathrm{E_f}}$$

ex $$250000\mathrm{kg} = \frac{12400\mathrm{kg} + 12600\mathrm{kg}}{1 - 0.4 - 0.5}$$

23) Takeoff Weight given Empty Weight Fraction

Open Calculator

fx $$\mathrm{DTW} = \frac{\mathrm{OEW}}{\mathrm{E_f}}$$

ex $$250000\mathrm{kg} = \frac{125000\mathrm{kg}}{0.5}$$

24) Takeoff Weight given Fuel Fraction

Open Calculator

fx $$\mathrm{DTW} = \frac{\mathrm{FW}}{\mathrm{F_f}}$$

ex $$250000\mathrm{kg} = \frac{100000\mathrm{kg}}{0.4}$$

25) Velocity at Maximum Endurance given Preliminary Endurance for Prop-Driven Aircraft

Open Calculator

fx $$V_{(Emax)} = \frac{LDEmax_{ratio} \cdot \eta \cdot \ln\left(\frac{W_{L(beg)}}{W_{L,end}}\right)}{c \cdot E}$$

ex $$40.00497\text{kn} = \frac{26 \cdot 0.93 \cdot \ln\left(\frac{400\text{kg}}{300\text{kg}}\right)}{0.6\text{kg/h/W} \cdot 2028\text{s}}$$

26) Velocity for Maximizing Range given Range for Jet Aircraft

Open Calculator

fx $$V_{L/D(max)} = \frac{R \cdot c}{LDmax_{ratio} \cdot \ln\left(\frac{W_i}{W_f}\right)}$$

ex $$42.79419\text{kn} = \frac{1000\text{km} \cdot 0.6\text{kg/h/W}}{19.7 \cdot \ln\left(\frac{514\text{kg}}{350\text{kg}}\right)}$$

27) Winglet Friction Coefficient

Open Calculator

fx $$\mu_{friction} = \frac{4.55}{\log 10\left(Re_{wl}^{2.58}\right)}$$

ex $$0.476772 = \frac{4.55}{\log 10\left((5000)^{2.58}\right)}$$

Variables Used

- **AR** Aspect Ratio of a Wing
- **c** Power Specific Fuel Consumption *(Kilogram per Hour per Watt)*
- C_D Drag Coefficient
- C_L Lift Coefficient
- **DTW** Desired Takeoff Weight *(Kilogram)*
- **E** Endurance of Aircraft *(Second)*
- E_f Empty Weight Fraction
- F_f Fuel Fraction
- **FW** Fuel Weight to be Carried *(Kilogram)*
- G_T Weight of Fuel *(Kilogram)*
- K_{LD} Landing Mass Fraction
- $LDEmax_{ratio}$ Lift to Drag Ratio at Maximum Endurance
- $LDmax_{ratio}$ Maximum Lift-to-Drag Ratio of Aircraft
- **OEW** Operating Empty Weight *(Kilogram)*
- P_E Preliminary Endurance of Aircraft *(Second)*
- **PYL** Payload Carried *(Kilogram)*
- **R** Range of Aircraft *(Kilometer)*
- R_D Design Range *(Kilometer)*
- R_H Harmonic Range *(Kilometer)*
- R_{opt} Optimum Range of Aircraft *(Kilometer)*
- Re_{wl} Winglet Reynolds Number
- **S** Reference Area *(Square Meter)*

- **S_{wet}** Aircraft Wetted Area *(Square Meter)*
- **$V_{(Emax)}$** Velocity for Maximum Endurance *(Knot)*
- **$V_{L/D(max)}$** Velocity at Maximum Lift to Drag Ratio *(Knot)*
- **W_a** Aircraft Weight *(Newton)*
- **W_c** Crew Weight *(Kilogram)*
- **W_f** Weight of Aircraft at End of Cruise Phase *(Kilogram)*
- **W_i** Weight of Aircraft at Beginning of Cruise Phase *(Kilogram)*
- **$W_{L(beg)}$** Weight of Aircraft at Beginning of Loiter Phase *(Kilogram)*
- **$W_{L,end}$** Weight of Aircraft at End of Loiter Phase *(Kilogram)*
- **ΔR** Range Increment of Aircraft *(Kilometer)*
- **η** Propeller Efficiency
- **η_r** Rotor Efficiency
- **$\mu_{friction}$** Coefficient of Friction
- **ξ** Coefficient of Power loss

Constants, Functions, Measurements used

- Function: **ln**, ln(Number)
  The natural logarithm, also known as the logarithm to the base e, is the inverse function of the natural exponential function.
- Function: **log10**, log10(Number)
  The common logarithm, also known as the base-10 logarithm or the decimal logarithm, is a mathematical function that is the inverse of the exponential function.
- Measurement: **Length** in Kilometer (km)
  Length Unit Conversion
- Measurement: **Weight** in Kilogram (kg)
  Weight Unit Conversion
- Measurement: **Time** in Second (s)
  Time Unit Conversion
- Measurement: **Area** in Square Meter (m²)
  Area Unit Conversion
- Measurement: **Speed** in Knot (kn)
  Speed Unit Conversion
- Measurement: **Force** in Newton (N)
  Force Unit Conversion
- Measurement: **Specific Fuel Consumption** in Kilogram per Hour per Watt (kg/h/W)
  Specific Fuel Consumption Unit Conversion

Check other formula lists

- **Preliminary Design Formulas**

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